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METHOD AND DEVICE FOR PREDICTING THE STARTING ABILITY OF A VEHICLE

FIELD OF THE INVENTION

The present invention relates to a device and method for predicting the starting ability of a vehicle.

5 ## BACKGROUND INFORMATION

Due to the increasing number of silent consumers such as the IR receiver of the central locking system, anti-theft device, sensors, etc., vehicles have substantial power consumption, even when shut off. There is the risk that a shut-off vehicle

10 may no longer be able to be started after a prolonged standstill. Therefore, devices indicating the starting ability are used to inform the driver.

A device for predicting the starting ability of a vehicle

15 indicates how long a vehicle may be shut off until the vehicle battery is discharged to a point that the vehicle is just able to be restarted or whether a start is still possible after a predefined time has elapsed. The starting ability of a vehicle is normally assumed when the battery is able to provide a

20 predefined electric starting power without falling short of a set minimum terminal voltage.

German Patent Application No. DE 197 05 634, for example, describes determining the starting ability of a vehicle at a

25 predefined starting current and a given starting temperature by calculating the terminal voltage of the battery during a starting operation. The terminal voltage is calculated from the no-load voltage and the internal resistance of the starter battery. The starting current is measured during the starting

30 operation. A prediction about a future starting ability of a

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vehicle is not possible. In addition, it is relatively complex
to measure the starting current of the battery during a
starting operation.

5   A method for determining the starting ability of a vehicle is
described in German Patent Application No. DE 1056970 in which
an average voltage drop in the battery is calculated during a
starting phase and it is determined whether or not a minimum
terminal voltage of the battery was not met. This method also
10   places high demands on the sensor for measuring the battery
voltage and additionally requires constant calculation of the
battery behavior during a starting operation. Moreover, a
prediction about the future starting ability of a vehicle is
not possible.

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SUMMARY
An object of the present invention is to provide a device and
a method for predicting the future starting ability of a
vehicle in which absolutely no measurements of starting
20   currents or voltages of the vehicle battery are necessary.

In accordance with the present invention, the future starting
ability of a vehicle is determined not on the basis of
measured starting currents or voltages, but rather, the
25   starting ability of the vehicle is determined based on a
characteristics map (composed of one or multiple
characteristic curves) of an electrical battery variable such
as the starting current. For this purpose, a characteristics
map, in which the dependency of an electrical battery
30   variable, e.g., the starting current flowing through the
starter, on a second battery variable, e.g., the state of
charge SOC of the battery, is represented, is stored in the
device for predicting the starting ability. The value of the
first electrical battery variable present during a future

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starting operation, e.g., a starting current value, may be
easily read out from the characteristics map when the future
second battery variable, e.g., the future state of charge
(SOCnew), is known. The value read out from the
characteristics map is a measure of the starting ability of
the vehicle at the future starting instant. This method has
the advantage that absolutely no starting currents or voltages
have to be measured during the start in order to determine the
starting ability.

The characteristics map of the electrical battery variable may
be determined for a predefined battery type and a predefined
starting system via measurements on the test bench. The
empirically determined characteristics map subsequently has
only to be stored in the prediction system, so that the
anticipated value of the first electrical battery variable,
such as the future battery current or battery voltage, may be
determined. As a function of the second battery variable, the
device in which the characteristics map is stored outputs the
value of the first electrical battery variable which would be
present during a future starting operation. The output
variable of the device is, for example, a starting current or
a battery voltage which appears during a future starting
operation and may be used to determine the starting ability.

According to a preferred example embodiment of the present
invention, the device for predicting the starting ability of a
vehicle includes a battery state detection device for
determining the state of charge (SOC) of the vehicle battery,
a device which determines charge (deltaSOC) drawn from the
vehicle battery during a predefined shut-off period from the
discharge current curve in the shut-off vehicle and calculates
remaining state of charge (SOCnew) of the vehicle battery
after the predefined shut-off period, a device for determining

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a first electrical battery variable from a stored
characteristics map which outputs a value of the electrical
battery variable which would appear during a future start, and
a prediction device which determines, based on the output
5   electrical battery value, whether the vehicle is able to start
after the predefined shut-off period.

The characteristics map may be stored either in the form of a
function or in the form of value pairs. The characteristic
10   curves of the characteristics map are preferably current,
voltage, or charge characteristic curves as a function of the
state of charge of the battery, for example.

Greater prediction accuracy may be achieved if the temperature
15   dependency of the battery and the starting system is taken
into account. In this case, the characteristics map is
additionally a function of temperature T.

The temperature prevailing at a future start may be determined
20   using a device for temperature prediction, for example. Since
it is impossible to accurately predict the temperature
prevailing at the starting instant (the nighttime temperature
may substantially differ from the daytime temperature), an
average of already measured temperatures is preferably
25   determined over a predefined period. For generating an
average, a low-pass filter, situated downstream from the
temperature sensor, may be used, for example. The temperature
average is preferably taken into account in determining the
first electrical battery variable.
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A characteristics map of a mechanical variable of the starting
system (the starting system includes all driven parts up to
the engine), such as a torque characteristics map as well as
an engine torque characteristic curve, is preferably stored in

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the prediction device. The torque characteristics map of the
starting system is preferably also determined via test bench
measurements.

5   The torque characteristics map of the starting system is a
function of an electrical battery variable, e.g., the state of
charge or the internal resistance of the battery. As a
function of the determined first electrical battery variable,
the associated torque characteristic curve is determined from
10   the torque characteristics map under consideration of at least
state of charge SOCnew. The prediction device may thus
determine the starting ability of the vehicle via a torque
comparison.

15   The prediction accuracy may be improved again if the
temperature is taken into account in determining the starting
torque. The characteristic curves of the torque
characteristics map of the starting system may therefore also
be stored as a function of the temperature.
20

The characteristics map of the first electrical battery
variable may be optionally adapted to the instantaneous state
of the starting system which is influenced by different
operating variables. The characteristics map of the first
25   electrical battery variable is, as mentioned above, determined
via test bench measurements under defined conditions, such as
a defined coolant temperature, a defined battery internal
resistance, a defined state of glow plugs, etc. A change of
these parameters affects the electrical battery variables,
30   e.g., the starting current, during a starting operation. The
actually occurring starting current may thus deviate, for
example, from the starting current measured on the test bench.
The stored characteristics map of the electrical battery
variable may be adapted to changed operating conditions in

that the starting current is measured during a starting
operation and the characteristics map is adapted accordingly.
Using this adaptation algorithm, aging of the internal
combustion engine and of components of the starting system in
5   particular, as well as battery and oil changes, may be taken
into account.

According to a preferred example embodiment, characteristics
maps for different starting systems and engines are stored in
10   the prediction device. The starting system includes all parts
of the vehicle which are important for predicting the starting
ability, such as, in particular, the transmission, the
battery, the starter, etc.

15   BRIEF DESCRIPTION OF THE DRAWINGS
An example embodiment of the present invention is described in
greater detail below based on the figures.

Figure 1 shows a schematic representation of a device for
20   predicting the starting ability of a vehicle according to an
example embodiment of the present invention.

Figure 2 shows a torque characteristics map of the starting
system stored in a prediction device for determining the
25   starting ability of the vehicle.

Figure 3 shows example method steps of a method for predicting
the starting ability of a vehicle.

30   DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS
Figure 1 shows a schematic representation of a device for
predicting the starting ability of a vehicle. The starting
ability of the vehicle is assumed when a vehicle battery 1 is
able to provide sufficient electrical starting power after a

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predefined shut-off period t_{off} in order to start the vehicle
without falling short of a predefined minimum terminal
voltage.

5   The vehicle battery is drained by different silent consumers
during the vehicle's shut-off period. Particularly when the
battery is weak, the driver must be informed whether the
vehicle is able to start after a predefined period, e.g.,
three days. Alternatively, the driver may also be informed as
10   to how long the vehicle will still be able to start.

Prediction of the starting ability generally relies on
determining a future state of charge SOCnew which vehicle
battery 1 will have after predefined shut-off period t_{off} and
15   using future state of charge SOCnew to determine starting
current I_{start}, flowing in the starter during a starting
operation, from a starting current characteristics map stored
in a device 3. Based on determined future starting current
I_{start}, it is possible to predict whether the vehicle will be
20   able to start using a prediction device 4.

Using the device for predicting the starting ability, it may
optionally also be predicted how long the vehicle will still
be able to start. This may be determined, for example, in that
25   shut-off period t_{off} is increased until the result is negative.

A characteristics map of the starting current for different
states of charge SOC of starter battery 1 is stored in device
3 for determining a starting current I_{start}. The starting
30   current characteristics map may be obtained via test bench
measurements and subsequent interpolation of the measured
values or via computer simulation. Starting current I_{start},
anticipated to flow at a future start, may simply be read out
from the characteristics map when future state of charge

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SOCnew of the battery and possibly the future starting
temperature are known. Therefore, no measurement of the
battery voltage or the battery current (starting current)
during a starting operation is necessary for predicting the
5   starting ability.

Starting current value I_{start} determined from characteristics
map 3 defines the starting torque generated by the starting
system. Given starting current value I_{start} is converted into a
10   torque value for predicting the starting ability of the
vehicle. As shown in Figure 2, a torque characteristics map of
starting system $M_{startsystem}$ is stored in prediction device 4.
Shown torque characteristic curve 10 again depends on state of
charge SOC or on internal resistance Ri and optionally also on
15   temperature T of the starting system. This torque
characteristics map $M_{startsystem}$ is also determined via test bench
measurements or simulations.

Moreover, prediction device 4 contains an engine torque
20   characteristic curve 11 which is generally constant. The
actually acting starting torque M at the future starting
instant arises at the intersection of engine torque
characteristic curve 11 and torque characteristic curve 10 of
the starting system (as a function of future state of charge
25   SOCnew).

The starting ability of the vehicle is established when torque
M, determined in such a way, is greater than a required
minimum torque M_{min}.
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During shut-off period t_{off} of the vehicle, current is
constantly drained from the battery by different switched-on
silent consumers. A device 5, which calculates the drained
charge by simply integrating the discharge current, for

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example, is provided for calculating the drained charge. The
discharge current in the shut-off vehicle is preferably
measured just after the vehicle is shut off. A more accurate
determination of the drained charge may be achieved when the
5   discharge current is measured at multiple points in time after
the vehicle is shut off.

Instantaneous state of charge SOC of battery 1 is determined
by a conventional battery state detection device 2.
10   Corresponding sensors (not shown) provide battery state
detection device 2 with battery temperature T_{Bat}, battery
voltage U_{Bat}, and battery current I_{Bat} as input variables.

State of charge SOCnew of battery 1, which appears after
15   predefined shut-off period t_{off}, is calculated by subtracting
drained charge deltaSOC from instantaneous charge SOC at
subtractor node 9. Subtractor 9, as well as other devices of
the prediction system, are preferably implemented in the form
of software and run in a control unit, for example.
20

The prediction accuracy may be improved when the starting
current characteristic curves are additionally stored as a
function of different starting temperatures and the starting
temperature is taken into account in the prediction. For this
25   purpose, the prediction system includes a temperature sensor
which measures the ambient temperature. The ambient
temperature is supplied to a device 6 for predicting the
starting temperature, device 6 evaluating a starting
temperature which is anticipated to prevail at the starting
30   instant. For this purpose, an average is preferably formed
from multiple temperature values, e.g., the temperature values
of the last several hours. In the simplest case, averaging may
take place via a low-pass filter having a large time constant
and an averaging function.

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Device 3 for determining starting current I_{start} preferably
includes starting current characteristic curves for different
starting systems, i.e., for different starter, engine,

5   transmission types, etc. For calculating the torque demand of
the starting system, the displacement, the number of
cylinders, the engine type (diesel/gasoline), additional
consumer currents (e.g., associated with glow plugs), the
transmission type (stick shift or automatic transmission) with

10   corresponding drag torque, and the battery type are of
importance. Instantaneous parameters P1...Pi of the starting
system are supplied to a selection unit 7 which selects the
starting current characteristic curve appropriate for the
starting system.

15

As mentioned above, the starting current characteristics map
is determined via test bench measurements or simulation under
defined ancillary conditions (ambient temperature, battery
type, state of the glow plugs, etc.). These parameters may

20   change during the course of operation. If the instantaneous
values are not taken into account when determining the future
starting current, the actually occurring starting current may
deviate from starting current I_{start} read out from the
characteristic curve. Therefore, the characteristics map is

25   preferably adapted to the instantaneous conditions.

For this purpose, starting current measurements, for example,
are carried out and the starting current characteristics map,
for example, is adapted accordingly by displacing the

30   characteristic curves. Provided that they are known, different
parameters Pk...Pz (ambient temperature, battery type, state
of the glow plugs, etc.) may optionally also be taken into
account in order to select the appropriate starting current
characteristic curve. In this case, the starting current

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characteristic curves would be stored as a function of these parameters. Using this adaptation algorithm, the wear and tear in the internal combustion engine and the starting system, in particular, as well as the aging of the battery and oil

5 changes, may be taken into account.

Figure 2 shows the determination of the starting ability of the vehicle using torque characteristic curves.

10 For determining an operating point M, which appears during a starting operation, engine torque M_{engine} over speed n and a characteristics map of starting system torque $M_{startsystem}$ are stored in prediction device 4. The torque of starting system $M_{startsystem}$ is in turn a function of state of charge SOC,

15 internal resistance Ri of battery 1, and starting temperature T_{start}. If state of charge SOC of the battery is low, torque $M_{startsystem}$, exerted by the starting system, is reduced in the direction of the dashed line which represents the torque curve at the lowest state of charge SOC needed for a successful

20 start.

The characteristics map of starting system torque $M_{startsystem}$ is again determined via test bench measurements or simulation.

25 Prediction device 4 determines operating point M from starting current I_{start} supplied by device 3 under consideration of state of charge SOCnew of battery 1 and possibly temperature T and internal resistance Ri. Torque M, acting on the engine, occurs at the point where torque $M_{startsystem}$, exerted by the starting

30 system, is equal to engine torque M_{engine}. If this operating point M is greater than a minimally required torque M_{min}, the vehicle is able to start after predefined shut-off period t_{off}.

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In order to determine how long the vehicle may be shut off in total without losing its starting ability, predefined shut-off period t_{off} is incrementally increased until operating point M is within predefined minimum limits M_{min}, n_{min}. Preceding time value t_{off} then approximately reflects the maximum shut-off period.

Figure 3 shows example steps of a method for predicting the starting ability of a vehicle. Instantaneous state of charge SOC of vehicle battery 1 is determined in a first step 20 via a battery state detection device 2. Charge deltaSOC, which is drained from vehicle battery 1 during a predefined time period t_{off} in the shut-off vehicle, is determined in step 21 and state of charge SOCnew of vehicle battery 1 after predefined time period t_{off} is calculated in step 22. In step 23, an electrical battery variable, e.g., future starting current I_{start} on the basis of calculated future state of charge SOCnew of vehicle battery 1, is read out from a characteristics map stored in device 3. Read out starting current value I_{start} is converted into a torque and compared in step 24 to a minimally required torque M_{min} to determine whether the vehicle is able to start (case J) or not (case N) after predefined time period t_{off}. The torque comparison is carried out in a prediction device 4. The result is displayed in block 25 or 26 via a suitable display element.